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MONO G-E-M

RESOURCES AREA

(GRA NO. CA-03)

TECHNICAL REPORT

(WSAs CA 010-088S-1/2, 010-090, and 010-092)

Contract YA-553-RFP2-1054

Prepared By

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For

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Final Report

April 22, 1983

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ATTACHMENTS
(At End of Report)

CLAIM AND LEASE MAPS

Patented/Unpatented

Geothermal

MINERAL OCCURRENCE AND LAND CLASSIFICATION MAPS (Attached)

Metallic Minerals

Uranium and Thorium

Nonmetallic Minerals

Geothermal

LEVEL OF CONFIDENCE SCHEME

CLASSIFICATION SCHEME

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U.S. GEOLOGICAL SURVEY

EXECUTIVE SUMMARY

The Mono Geology-Energy-Minerals (GEM) Resources Area (GRA) is in central Mono County, California between Mono Lake and the Nevada border. The nearest town in Benton, about 10 miles southeast of the middle of the GRA. There are three Wilderness Study areas (WSAs) in the GRA: WSAs CA 010-088S-1/2, 010-090, and 010-092.

Much of the northern part of the GRA, including all of the WSA CA 010-092, is covered by lake sediments deposited within the last half-million years when Mono Lake was much larger than it presently is. A large part of the GRA is covered by volcanic rocks about 10 million years old. In the southwest corner of the GRA are exposures of granitic rocks about 100 million years old that elsewhere in the region are seen to be intruded into much older sedimentary rocks and in some such places deposits of metallic minerals are related to these granites.

There are no mining districts in the Mono GRA and no known mineral production, though one adit symbol on the topographic quadrangle is labeled as a "mine". There are no oil or gas leases, no geothermal leases, and no sodium or potassium leases.

WSA CA 010-088S-1/2 is classified as having low potential, with very low confidence in its entirety for metallic mineral resources, such as copper and/or tungsten deposits in older rocks hidden under the Tertiary and Quaternary cover. Parts of the three segments are classified as having low potential, with low confidence, for uranium and thorium in alluvium. The WSA has low to no potential for thorium with very low confidence. Parts of the WSA are classified as having moderate potential, with moderate confidence, for sand and gravel in alluvium. The WSA is classified as having moderate potential, with low confidence, for geothermal resources on the basis of young volcanics that indicate a heat source, and structure that may provide conduits for hot water. The WSA is classified as having very low potential, with high confidence, for oil and gas and for sodium and potassium.

WSA CA 010-090 is partly classified as moderately favorable for metallic minerals, with moderate confidence, in the vicinity of a reported molybdenum prospect and in the vicinity of old diggings. An area of granitic outcrops is classified as having very low favorability for metals, with low confidence, while the remainder of the WSA has low favorability for metals, with very low confidence. Two parts of the WSA have low favorability for uranium with low confidence, another part has low favorability with very low confidence, and another part has moderate favorability, with low confidence. Most of the WSA has low favorability for thorium with low to very low confidence. Three small areas are classified as having moderate favorability for sand and gravel deposits, with moderate confidence, and the remainder has low favorability for nonmetallic minerals with low confidence. Part of the WSA that lies within a USGS KGRA has high favorability for geothermal

resources, with high confidence, while the remainder has moderate favorability with low to moderate confidence. There is very low favorability, with high confidence, for oil and gas and for sodium and potassium.

WSA CA 010-092 has low favorability for metals throughout, with very low confidence. It has low favorability for uranium and for nonmetallic minerals, with low confidence. There is no favorability for thorium in the WSA with very low confidence. Part of it has high favorability for geothermal resources with high confidence, while the remainder has moderate favorability with low to moderate confidence. It has very low favorability for oil and gas and for sodium and potassium, with high confidence.

Field checks should be made of two areas with known prospecting about which nothing is known concerning the commodities sought or the nature of the work that was done.

I. INTRODUCTION

The Mono G-E-M Resources Area (GRA No. CA-03) contains approximately 262,000 acres (1,063 sq km) and includes the following Wilderness Study Areas (WSAs):

WSA Name	WSA Number
Excelsior (South 1/2)	010-088S-1/2
Granite Mountain	010-090
Walford Springs	010-092

The GRA is located in California in the Bureau of Land Management's (BLM) Bishop Resource Area, Bakersfield District. Figure 1 is an index map showing the location of the GRA. The area encompassed by the GRA is near 38°00' north latitude, 118°45' west longitude and includes the following townships:

T 3 N, R 27-31 E	T 2 N, R 27-31 E
T 1 N, R 27-31 E	T 1 S, R 27-31 E

The areas of the WSAs are on the following U. S. Geological Survey topographic maps:

15-minute:

Trench Canyon	Cowtrack Mountain
Glass Mountain	

The nearest town is Benton which is located southeast of the GRA at the intersection of State Highway 120 and U.S. 6. Access to the area is via State Highway 167 to the north and State Highway 120 to the south of the GRA. Access within the area is on numerous unimproved roads between these two highways.

Figure 2 outlines the boundaries of the GRA and the WSAs on a topographic base at a scale of 1:250,000.

Figure 3 is a geologic map of the GRA and vicinity, also at 1:250,000. At the end of the report, following the Land Classification Maps, is a geologic time scale showing the various geologic eras, periods and epochs by name as they are used in the text, with the corresponding age in years. This is so that the reader who is not familiar with geologic time subdivisions will have a comprehensive reference for the geochronology of events.

This GRA Report is one of fifty-five reports on the Geology-Energy-Minerals potential of Wilderness Study Areas in the Basin

and Range province, prepared for the Bureau of Land Management by the Great Basin GEM Joint Venture. The principals of the Venture are Arthur Baker III, G. Martin Booth III, and Dennis P. Bryan. The study is principally a literature search supplemented by information provided by claim owners, other individuals with knowledge of some areas, and both specific and general experience of the authors. Brief field verification work was conducted on approximately 25 percent of the WSAs covered by the study.

None of the WSAs in this GRA were field checked.

One original copy of background data specifically applicable to this GEM Resource Area Report has been provided to the BLM as the GRA File. In the GRA File are items such as letters from or notes on telephone conversations with claim owners in the GRA or the WSA, plots of areas of Land Classification for Mineral Resources on maps at larger scale than those that accompany this report if such were made, original compilations of mining claim distribution, any copies of journal articles or other documents that were acquired during the research, and other notes as are deemed applicable by the authors.

As a part of the contract that resulted in this report, a background document was also written: Geological Environments of Energy and Mineral Resources. A copy of this document is included with the GRA File to this GRA report. There are some geological environments that are known to be favorable for certain kinds of mineral deposits, while other environments are known to be much less favorable. In many instances conclusions as to the favorability of areas for the accumulation of mineral resources, drawn in these GRA Reports, have been influenced by the geology of the areas, regardless of whether occurrences of valuable minerals are known to be present. This document is provided to give the reader some understanding of at least the most important aspects of geological environments that were in the minds of the authors when they wrote these reports.

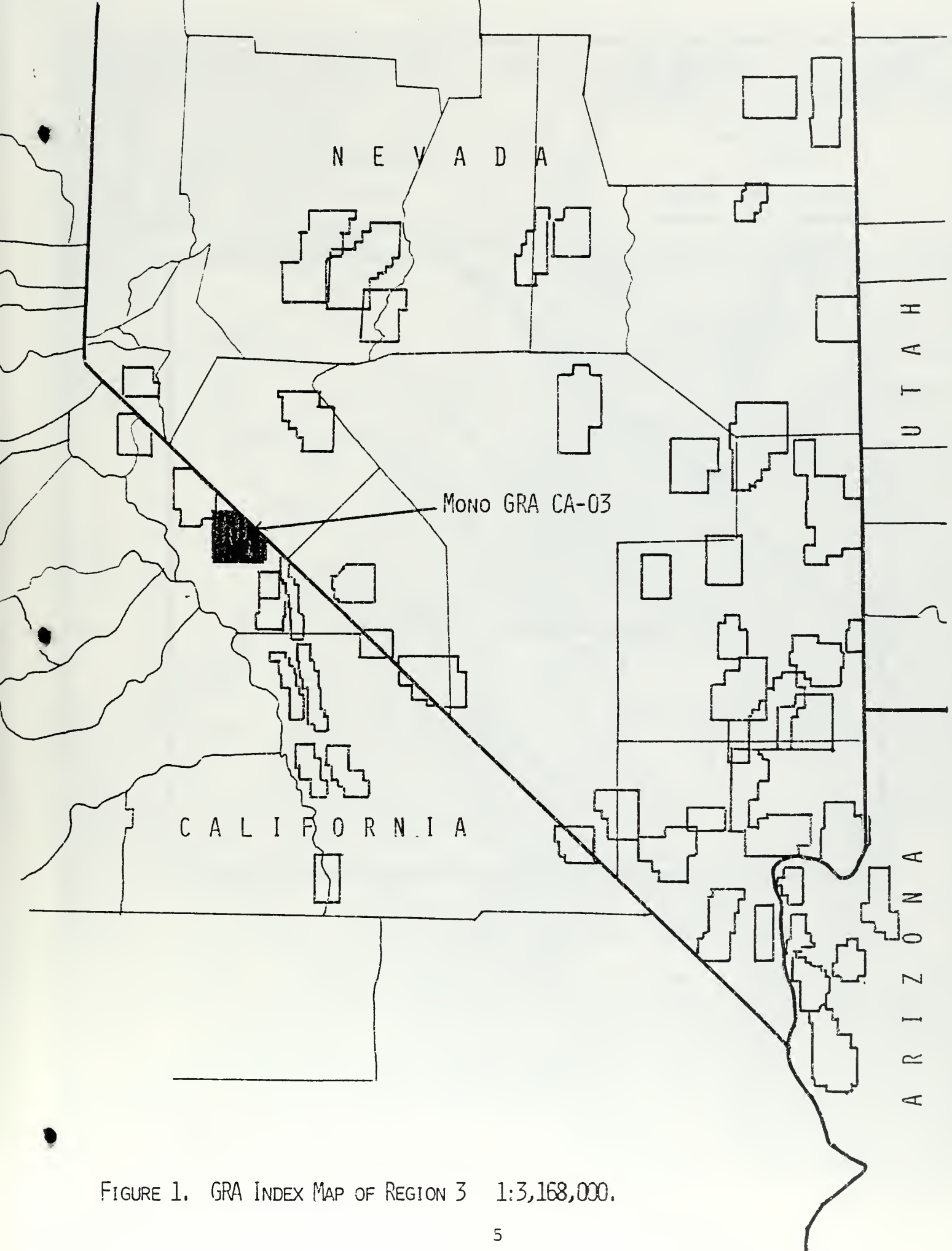
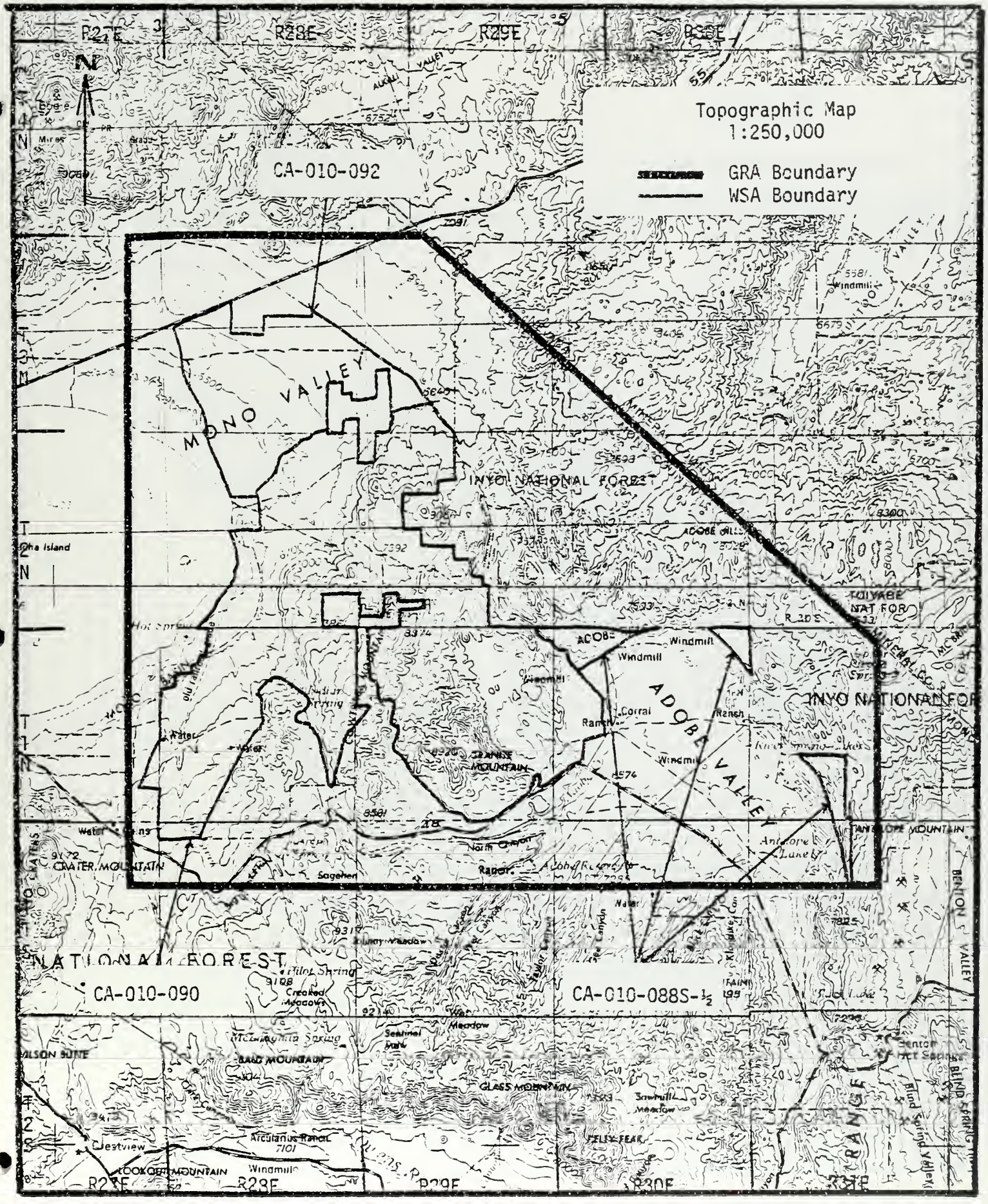


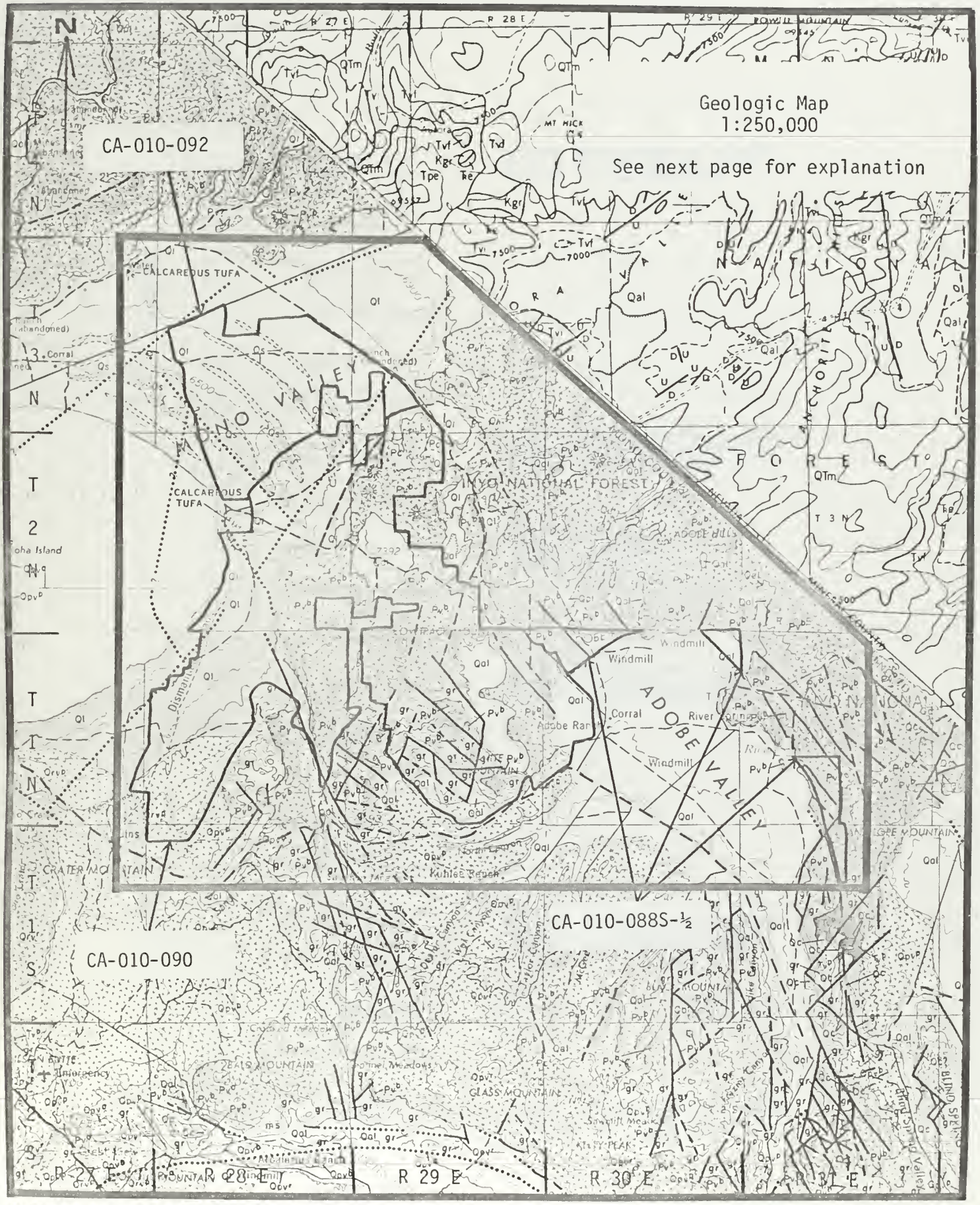
FIGURE 1. GRA INDEX MAP OF REGION 3 1:3,168,000.



Walker Lake and Mariposa Sheets

Mono GRA CA-03

Figure 2



Walker Lake Sheet, Koenig (1963);
Mariposa Sheet, Strand (1967)

Mono GRA CA-03

Figure 3

EXPLANATION

SEDIMENTARY AND METASEDIMENTARY ROCKS

CENOZOIC

QUATERNARY

Recent

- Qs — Dune sand
- Qal — Alluvium
- Qsc — Stream channel deposits
- Qf — Fan deposits
- Qb — Basin deposits

GREAT VALLEY

- Qsf — Salt deposits
- Q. — Quaternary lake deposits
- Qg — Glacial deposits

Pleistocene

- Qt — Quaternary nonmarine terrace deposits
- Qm — Pleistocene marine and marine terrace deposits
- Qc — Pleistocene nonmarine
- QP — Plio-Pleistocene nonmarine

TERTIARY

Pliocene

- Pc — Undivided Pliocene nonmarine
- Puc — Upper Pliocene nonmarine
- Pu — Upper Pliocene marine
- Pmlc — Middle and/or lower Pliocene nonmarine
- Pml — Middle and/or lower Pliocene marine

Miocene

- Mc — Undivided Miocene nonmarine
- Muc — Upper Miocene nonmarine
- Mu — Upper Miocene marine
- Mmc — Middle Miocene nonmarine
- Mm — Middle Miocene marine
- Ml — Lower Miocene marine

Oligocene

- Φc — Oligocene nonmarine
- Φ — Oligocene marine

Eocene

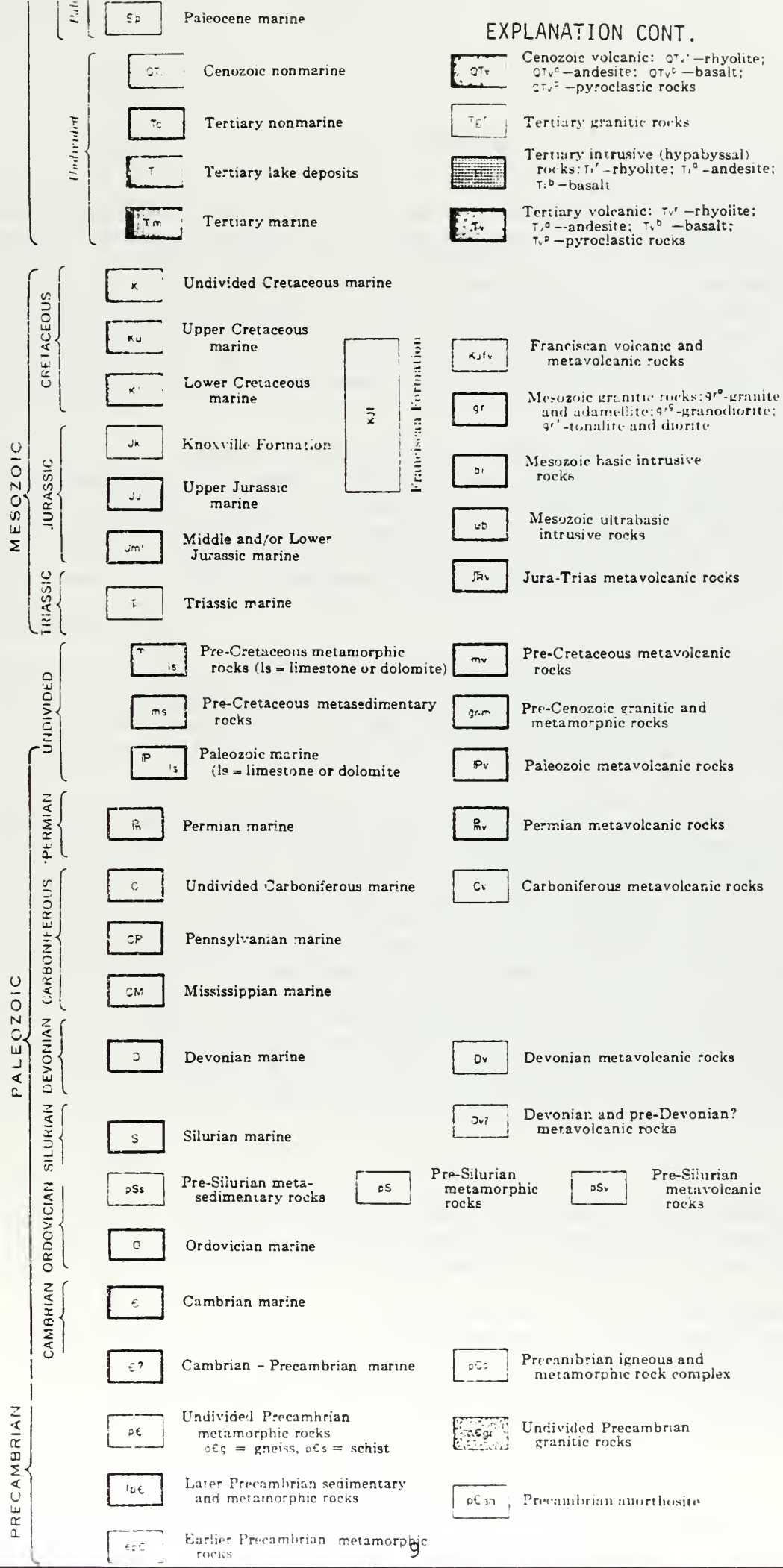
- Ec — Eocene nonmarine
- E — Eocene marine

Paleocene

- Epc — Paleocene nonmarine
- Ep — Paleocene marine

IGNEOUS AND META-IGNEOUS ROCKS

- Qrv — Recent volcanic: Q_{rv}^{r} —rhyolite; Q_{rv}^{a} —andesite; Q_{rv}^{b} —basalt; Q_{rv}^{p} —pyroclastic rocks
- Qpv — Pleistocene volcanic: Q_{pv}^{r} —rhyolite; Q_{pv}^{a}—andesite; Q_{pv}^{b} —basalt; Q_{pv}^{p} —pyroclastic rocks
- Quaternary and/or Pliocene cinder cones
- Pv — Pliocene volcanic: P_{v}^{r} —rhyolite; P_{v}^{a}—andesite; P_{v}^{b} —basalt; P_{v}^{p} —pyroclastic rocks
- Mv — Miocene volcanic: M_{v}^{r} —rhyolite; M_{v}^{a} —andesite; M_{v}^{b} —basalt; M_{v}^{p} —pyroclastic rocks
- Φv — Oligocene volcanic: Φ_{v}^{r}—rhyolite; Φ_{v}^{a} —andesite; Φ_{v}^{b}—basalt; Φ_{v}^{p}—pyroclastic rocks
- Ev — Eocene volcanic: E_{v}^{r} —rhyolite; E_{v}^{a} andesite; E_{v}^{b} —basalt; E_{v}^{p} —pyroclastic rocks


Paleocene marine
Undivided
Cenozoic nonmarine
Tertiary nonmarine
Tertiary lake deposits
Tertiary marine
EXPLANATION CONT.
Cenozoic volcanic: QTv^r—rhyolite; QTv^a—andesite; QTv^b—basalt; QTv^p—pyroclastic rocks
Tertiary granitic rocks
Tertiary intrusive (hypabyssal) rocks: Ti^r—rhyolite; Ti^a—andesite; Ti^b—basalt
Tertiary volcanic: Tv^r—rhyolite; Tv^a—andesite; Tv^b—basalt; Tv^p—pyroclastic rocks
MESOZOIC
CRETACEOUS
JURASSIC
TRIASSIC
Undivided Cretaceous marine
Upper Cretaceous marine
Lower Cretaceous marine
Knoxville Formation
Upper Jurassic marine
Middle and/or Lower Jurassic marine
Triassic marine
KJf
Franciscan Formation
Franciscan volcanic and metavolcanic rocks
Mesozoic granitic rocks: gr^a-granite and adamellite; gr^b-granodiorite; gr^c-tonalite and diorite
Mesozoic basic intrusive rocks
Mesozoic ultrabasic intrusive rocks
Jura-Trias metavolcanic rocks
PALEOZOIC
UNDIVIDED
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
Pre-Cretaceous metamorphic rocks (ls = limestone or dolomite)
Pre-Cretaceous metasedimentary rocks
Paleozoic marine (ls = limestone or dolomite)
Permian marine
Undivided Carboniferous marine
Pennsylvanian marine
Mississippian marine
Devonian marine
Silurian marine
Pre-Silurian meta-sedimentary rocks
Ordovician marine
Cambrian marine
Cambrian – Precambrian marine
Undivided Precambrian metamorphic rocks
pCg = gneiss, pCs = schist
Later Precambrian sedimentary and metamorphic rocks
Earlier Precambrian metamorphic rocks
PRECAMBRIAN
pS
Pre-Silurian metamorphic rocks
Pre-Cretaceous metavolcanic rocks
Pre-Cenozoic granitic and metamorphic rocks
Paleozoic metavolcanic rocks
Permian metavolcanic rocks
Carboniferous metavolcanic rocks
Devonian metavolcanic rocks
Devonian and pre-Devonian? metavolcanic rocks
pSv
Pre-Silurian metavolcanic rocks
Precambrian igneous and metamorphic rock complex
Undivided Precambrian granitic rocks
Precambrian anorthosite

II. GEOLOGY

The Mono GRA lies mainly within the Mono Basin, a post-Miocene northeast-trending structural depression. To the east and southeast of this basin, a thick sequence of Miocene through Pliocene volcanics have been deposited in a zone of extension formed by the intersection of two discrete fault patterns. The southwest portion of the study area is predominantly recent pyroclastic deposits and patches of Bishop Tuff. Granite basement rocks crop out in the southwest portion of the Mono GRA in a highly faulted area.

The terrane is moderate and contrasts greatly with the rugged Sierra Nevada to the west. The present topography has been formed by strike-slip and dip-slip faults which probably formed during the Miocene, but have been especially active during the last four million years. This recent tectonism is evidenced by the displacement of recent sediments and pyroclastic deposits.

1. PHYSIOGRAPHY

The Mono GRA is located in eastern Mono County, California. The study area, which includes the eastern half of Mono Lake, is approximately bounded in the south by California Highway 120 and on the east by the California-Nevada state line.

The topography is moderate, with elevations ranging from the approximately 6,380 foot elevation of Mono Lake to a maximum of 8,920 on Granite Mountain. Because the topography of the eastern part of the GRA results from relatively recent faulting and tilting rather than from erosion, there are numerous sharp ridges and small enclosed basins in this area. The northern part of the GRA is a broad plain, Mono Valley underlain by lake sediments deposited when Mono Lake had much greater extent than it presently does. In the southeastern part is Adobe Valley, another broad plain that is an enclosed basin but with a very low pass closing off drainage to the south and thence to the Owens Valley depression. Except in the Adobe Valley area, streams discharge into Mono Lake.

2. ROCK UNITS

The oldest rocks in the Mono GRA are several exposures of an unnamed Cretaceous granitic intrusion related to the Sierra Nevada Batholith in the southwestern portion of the GRA.

Intrusive rocks with some roof pendants of metasediments and metavolcanics constitute the basement of the region and are unconformably overlain by a thick sequence of Miocene to Recent volcanics. These volcanic rocks have been dated by K-Ar methods by Gilbert and others (1968). All dates pertaining to volcanics in this discussion have been derived from Gilbert's analysis.

The oldest volcanics are unnamed Early Miocene rhyolitic ignimbrites overlain by andesite. These rocks are older than and structurally unrelated to the Mono Basin. They occur as isolated patches in the area east of Adobe Valley, the Cowtrack Mountain area and the northeast corner of the study area.

The next oldest volcanics are Early Pliocene latite ignimbrites which crop out east of Mono basin.

Older sediments of the eastern Mono basin, consisting of tuffaceous silts, sands, gravels and diatomites, occur on the eastern margin of Mono basin. These fossiliferous sediments are intercalated with olivine basalt flows, and are probably pre-Pleistocene in age. The olivine basalt flows cover a large portion of the area east and southeast of Mono basin. Numerous cinder cones dot this volcanic terrane.

The Bishop Tuff was deposited in the area southeast of Mono Lake during the Late Pleistocene. Late Pleistocene pluvial lake deposits occur along the rim of Mono Lake up through the northeast trend of Mono Valley.

During recent times pyroclastics have been deposited north of the Mono Craters in the southwest portion of the study area.

3. STRUCTURAL GEOLOGY AND TECTONICS

Both dip-slip and strike-slip faulting in the Mono GRA can be conveniently termed as pre- or post-Pliocene basalt faulting. It has been documented by Gilbert and others (1968) that many of the pre-basalt faults were reactivated after the basalt was extruded. The general pattern for both ages of faults is very similar and the record of the earlier structural movements is meager. The regional character of deformation can best be described in terms of movements that affected the widespread basalt.

Warping and dip-slip faulting during the last three to four million years have been responsible for most of the relief in the study area.

Vertical post-basalt movement is commonly a dominant warping on the west side of a topographic high, and faulting on the east side. This pattern is found at Cowtrack Mountain and in the Anchorite Hills.

The Mono basin is a broad shallow warp that developed during the last three to four million years. The basin is bounded by the Sierra Nevada escarpment on the west and by broad flexures on the northern, eastern and southern margins. The eastern margin of the basin consists of a complex pattern of faults and flexures with the principal faults trending northeast with left-lateral movement. More than 1000 feet of left-lateral

slip during the last two and one-half million years has been documented in the Anchorite Pass area.

A structural "knee" (Gilbert and others, 1968) separates the area of northeast-trending left-lateral northern faults and northwest-trending right-lateral(?) faults to the south. The intersection of these faults produced an area of extension along which the voluminous Pliocene-Pleistocene volcanic eruptions have occurred east of Mono Lake.

It is known that the left-lateral motions are still active. The 1934 earthquake in the Excelsior Mountains ten miles east of the GRA produced left-lateral displacement on a northeast trending fault.

4. PALEONTOLOGY

The principal lithology in the GRA is Pliocene volcanics, mostly basalts (Pv), and Quaternary lake sediments (Ql), dune sands (Qs) and alluvium (Qal). Occurrences of other lithologic units such as Mesozoic granitic rocks (gr) and Pleistocene volcanics are subordinate. Only Quaternary lake deposits hold any paleontological potential, and that is considered to be low as their environment of deposition (chemically) was not suitable for preservable lacustrine biota, including mollusks. Older gravels of Mono Lake (actually pluvial Lake Russell) are known to be abundantly fossiliferous northeast of the present study area, but the fossiliferous horizons do not extend into the Mono GRA.

5. HISTORICAL GEOLOGY

During the Cretaceous a series of granitic intrusions related to the Sierra Nevada batholith were emplaced into Paleozoic sediments and volcanics. A period of erosion followed until the Miocene when a series of rhyolitic ignimbrites, andesite flows and breccias were deposited unconformably over the intrusives.

The Pliocene epoch began with eruptions of latite ignimbrites east of Mono Basin lasting until about 7.5 million years ago when volcanism in the area ceased. Deformation of the study area began during this time, but much of the evidence has been masked by subsequent volcanic deposits.

Volcanic activity and local lacustrine sedimentation resumed about 4.5 million years ago with the deposition of freshwater deposits and thick basalt flows in the eastern and southeastern portion of the study area. Warping and faulting, especially active after the deposition of the basalt, created much of the present topography. These movements have been active to the present time as evidenced by fault displacement of recent sediments in the Excelsior Mountains.

III. ENERGY AND MINERAL RESOURCES

A. METALLIC MINERAL RESOURCES

1. Known Mineral Deposits

There are no known mineral deposits in the Mono GRA.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

On the Cowtrack Mountain topographic quadrangle map an adit symbol with the word "mine" is shown in the NW 1/4 of Sec. 21, T 1 N, R 21 E, about a mile and one-half northwest of Granite Mountain. Two prospect symbols are shown about a mile north of the adit symbol, and another about a mile east of it. These are the only known old prospects in the GRA. No reference to them was found in the literature.

Occidental Minerals staked claims in the western part of WSA CA 010-090, reportedly for molybdenum, but no furhter information is available.

3. Mining Claims

There are no patented claims in the GRA.

A very small number of unpatented claims are northwest of Granite Mountain, probably covering the adit and the prospects that appear on the Cowtrack Mountain topographic quadrangle. They are in WSA 010-090. Farther west there are probably more than a hundred claims in a three-mile wide band running north-south through the middle of T 1 N, R 28 E. The pattern of these claims -- claims in all four quarters of several adjacent sections -- suggests that the staking blankets complete sections and was done by a major mining company that has some concept that indicates the area is favorable for mineral resources. At least some of the claims are Occidental's. Occidental had withdrawn from hard minerals exploration at the time of this study. The individual contacted at Occidental's Denver office said that the company's only activity in the Mono Lake area had been in connection with the waters of the lake itself. Some of the claims are named "Pumice", and these will be considered under Nonmetallic Minerals. About half of these claims are in WSA 010-090.

4. Mineral Deposit Types

There is no direct information as to mineral deposit types in the GRA.

The prospects northwest of Granite Mountain are in a granitic terrane according to the Mariposa sheet of the Geologic Map of California. The diggings are presumably old, and therefore are likely to have at least some precious metals present, since those were of princpial interest to the old timers. They may be: (1) occurrences of mesothermal precious metal-base metal quartz veins such as are found in the Casa Diablo district 20 miles southeast, (2) epithermal precious metal veins like those of Bodie 15 miles northwest, or (3) tungsten occurrences related to the pluton of Granite Mountain.

The area of intensive staking in the southwestern part of the GRA is one of varied geology. There are areas of Mesozoic granitic rocks, Pliocene basalts, Quaternary pyroclastics (the edge of exposures of the Bishop Tuff), and Quaternary lake deposits formed when Mono Lake was at higher levels than it now is. A hot spring is shown on the geologic map, at the edge of Mono Lake and a couple of miles west of the staked area.

5. Mineral Economics

Any mineral deposits found in near-surface rocks that can be open pit mined, will face no special economic problems.

The pre-Tertiary rocks which are potential hosts for tungsten deposits, and perhaps for other metals, lie at depths of some hundreds or thousands of feet below the surface under cover of volcanic rocks and sediments. Finding such deposits is very difficult with the present state of the art of mineral exploration. Presumably developments in the forseeable future will make such discoveries possible. If deposits are found in the pre-Tertiary rocks, they will have to be mined by underground techniques, which means they must be relatively rich.

The major use of gold is for storing wealth. It is no longer used for coinage because of monetary problems, but many gold "coins" are struck each year for sale simply as known quantities of gold that the buyer can keep or dispose of relatively easily. The greatest other use of gold is in jewelry, another form of stored wealth. In recent years industrial applications have become increasingly important, especially as a conductor in electronic instrumentation. In the United States and some other countries gold is measured in troy ounces that weigh 31.1 grams -- twelve of which make one troy pound. Annual world production is about 40 million ounces per year, of

which the United States produces somewhat more than one million ounces, less than one-fourth of its consumption, while the Republic of South Africa is by far the largest producer at more than 20 million ounces per year. World production is expected to increase through the 1980s. For many years the price was fixed by the United States at $35 per ounce, but after deregulation the price rose to a high of more than $800 per ounce and then dropped to the neighborhood of $400 per ounce. At the end of 1982 the price was $460.50 per ounce.

The major uses of silver are in photographic film, sterlingware, and increasingly in electrical contacts and conductors. It is also widely used for storage of wealth in the form of jewelry, "coins" or bullion. Like gold it is commonly measured in troy ounces, which weigh 31.1 grand grams, twelve of which make one troy pound. World production is about 350 million ounces per year, of which the United States produces about one-tenth, while it uses more than one-third of world production. About two-thirds of all silver is produced as a byproduct in the mining of other metals, so the supply cannot readily adjust to demand. It is a strategic metal. Demand is expected to increase in the next decades because of growing industrial use. At the end of 1982 the price of silver was $11.70 per ounce.

More than half of all tungsten used is in the form of tungsten carbide, a hard and durable material used in cutting tools, wear-resistant surfaces and hard-faced welding rods. Lesser quantities are used in alloy steels, in light bulb filaments, and in chemicals. World production of tungsten is nearly 100 million pounds annually, of which the United States produces somewhat more than six million pounds, while using more than 23 million pounds. The shortfall is imported from Canada, Bolivia, Thailand and Mainland China, as well as other countries. Tungsten is a strategic and critical metal. United States demand is projected to about double by the year 2000, and most of the additional supply will probably be imported, because large reserves are in countries in which profitability is not a factor -- they need foreign exchange, and therefore sell at a price that few domestic mines can match. Tungsten prices F.O.B. mine are quoted for "short ton units", which are the equivalent of 20 pounds of contained tungsten. At the end of 1982 the price of tungsten was about $80 per short ton unit.

B. NONMETALLIC MINERAL RESOURCES

1. Known Mineral Deposits

There are no known nonmetallic mineral deposits in the GRA.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

Quaternary alluvium which covers extensive areas in the GRA and in parts of the WSAs except CA 010-092, by definition, contains sand and gravel. Quaternary lake beds which cover much of WSA CA 010-092 and part of 010-090 do not necessarily contain sand and gravel.

3. Mining Claims, Leases and Material Sites

Some of the claims in the southwest corner of the GRA, in WSA CA 010-090, are named "Pumice", which suggests they were located for this material. No mineral leases are known in any of the WSAs. No material sites are known in any of the WSAs.

4. Mineral Deposit Types

Sand and gravel occur in alluvium, and indeed make up most of it. The quality of the sand and gravel at any given place is not known, but it is reasonable to expect that some of it is of high enough quality to serve as aggregate in concrete and other demanding uses. The remainder is at least good enough to serve as fill material.

5. Mineral Economics

Sand and gravel in general are such low-priced and easily available commodities that they can only be used close to the deposits in which they occur. The deposits in the Mono GRA will be used only when there are construction projects nearby. There are many pumice deposits that are closer to markets than are those in the Mono GRA.

The most common use of sand and gravel is as "aggregate" -- as part of a mixture with cement to form concrete. The second largest use is as road base, or fill. About 97 percent of all sand and gravel used in the United States is in these applications in the construction industry. The remaining three percent is used for glassmaking, foundry sands, abrasives, filters and similar applications. The United States uses nearly one billion tons of sand and gravel annually, all of it produced domestically except for a very small tonnage of sand that

is imported for highly specialized uses. Since construction is by far the greatest user of sand and gravel, the largest production is near sites of intensive construction, usually metropolitan areas. Since sand and gravel are extremely common nearly everywhere, the price is generally very low and mines are very close to the point of consumption -- within a few miles as a rule. However, for some applications such as high-quality concrete there are quite high specifications for sand and gravel, and acceptable material must be hauled twenty miles and more. Demand for sand and gravel fluctuates with activity in the construction industry, and is relatively low during the recession of the early 1980s. Demand is expected to increase by about one third by the year 2000. In the early 1980s the price of sand and gravel FOB plant averaged about $2.50 per ton but varied widely depending upon quality and to some extent upon location.

For statistical purposes pumice, volcanic cinder and scoria are treated together because in most applications they are interchangeable; the word "pumice" as used here includes the other materials. Because of its porous nature and resultant light weight (some pumice will float on water) about 40 percent of all pumice production is used as aggregate in making light-weight concrete for construction purposes. An equal amount is used as aggregate in road construction. A small amount is used in abrasives, while the remainder is used, mostly in finely-ground form, in a multitude of applications such as absorbents, carriers for insecticides, decolorizers and purifying agents, fillers and extenders for paints, and many others. United States consumption is about 4.5 million short tons annually, nearly all of which is produced domestically and most of which is produced within a very few hundred miles of the point of use because it is a high-volume, low-unit-price material. A small quantity of pumice for specialized uses is imported. United States demand for pumice is forecast to more than double by the year 2000, with domestic production keeping up with demand. In recent years the F.O.B. mine price for pumice as such has been about $4 per ton, while the price for the somewhat more common volcanic cinders has been about $3 per ton.

C. ENERGY RESOURCES

Uranium and Thorium Resources

1. Known Mineral Deposits

There are no known uranium or thorium deposits within or near the WSAs or the GRA.

2. Known Prospects, Mineral Occurrences and Mineralized Areas

There are no known uranium or thorium prospects or occurrences within or near the WSAs or the GRA.

3. Mining Claims

No information is published on uranium or thorium claims or leases within the GRA.

4. Mineral Deposit Types

There is no evidence for thorium deposits in or near the GRA. Uranium deposit types could be variable, though none are known in the GRA.

5. Mineral Economics

The lack of known uranium and thorium occurrences in the area prevents an economic determination of these minerals, though the economics would appear to be unfavorable for the GRA.

Uranium in its enriched form is used primarily as fuel for nuclear reactors, with lesser amounts being used in the manufacture of atomic weapons and materials which are used for medical radiation treatments. Annual western world production of uranium concentrates totaled approximately 57,000 tons in 1981, and the United States was responsible for about 30 percent of this total, making the United States the largest single producer of uranium (American Bureau of Metal Statistics, 1982). The United States ranks second behind Australia in uranium resources based on a production cost of $25/pound or less. United States uranium demand is growing at a much slower rate than was forecast in the late 1970s, because the number of new reactors scheduled for construction has declined sharply since the accident at the Three Mile Island Nuclear Plant in March, 1979. Current and future supplies were seen to exceed future demand by a significant margin and spot prices of uranium fell from $40/pound to $25/pound from January, 1980 to January, 1981 (Mining Journal, July 24, 1981). At present the outlook for the United States uranium industry is bleak. Low prices and overproduction in the industry have resulted in the closures of numerous uranium mines and mills and reduced production at properties which have remained in operation. The price of uranium at the end of 1982 was $19.75/pound of concentrate.

Thorium is used in the manufacture of incandescent gas mantles, welding rods, refractories, as fuel for nuclear power reactors and as an alloying agent. The principal source of thorium is monazite which is recovered as a byproduct of titanium, zirconium and rare earth recovery from beach sands. Although monazite is produced from Florida beach sands, thorium products are not produced from monazite in the United States. Consequently, thorium products used in the United States come from imports, primarily from France and Canada, and industry and government stocks. Estimated United States consumption of thorium in 1980 was 33 tons, most of which was used in incandescent lamp mantles and refractories (Kirk, 1980b). Use of thorium as nuclear fuel is relatively small at present, because only two commercial thorium-fueled reactors are in operation. Annual United States demand for thorium is projected at 155 tons by 2000 (Kirk, 1980a). Most of this growth is forecast to occur in nuclear power reactor usage, assuming that six to ten thorium-fueled reactors are on line by that time. The United States and the rest of the world are in a favorable position with regard to adequacy of thorium reserves. The United States has reserves estimated at 218,000 tons of ThO_2 in stream and beach placers, veins and carbonatite deposits (Kirk, 1982); and probable cumulative demand in the United States as of 2000 is estimated at only 1800 tons (Kirk, 1980b). The price of thorium oxide at the end of 1981 was $16.45 per pound.

Oil and Gas Resources

There are no known oil and gas deposits, hydrocarbon shows in wells, or surface seeps in the region; nor are there any Federal oil and gas leases in the immediate region. The geological environment -- igneous rocks and very young sediments -- is not favorable for the occurrence of oil and gas. There is no oil and gas lease map, nor oil and gas occurrence and land classification map in the report.

Geothermal Resources

1. Known Geothermal Deposits

The Mono GRA lies barely outside the 22 mile long north-south-trending Mono area known or inferred to be underlain at shallow depth (less than 1000 m) by thermal water of sufficient temperature for direct applications (see Geothermal Mineral Occurrence and Land Classification map).

2. Known Prospects, Geothermal Occurrences, and Geothermal Areas.

The known geothermal occurrences close to the Mono GRA which are within the deposit described under (1) above, are (NOAA, 1980):

Well/Spring	Temp.	Flow (l/min)	Salinity (mg/l)	Depth
Unnamed Springs	86°C	100	25,000	---
State PRC 4397.1 Well	54°C	---	---	1220 m
Unnamed Spring	42°C	150	2,500	---
Unnamed Spring (Mono Craters Tunnel)	36°C	---	---	---

On the eastern edge of the valley within the GRA is Warm Springs (31°C at 95 l/min; and salinity of 1930 mg/l).

Four miles outside the southeast corner of the Mono GRA boundary is an unnamed spring flowing 27°C water at 1045 l/min, and Bertrand Springs with a recorded temperature of 21°C and flowing 380 l/min. Nine miles to the south of the GRA is the large and highly prospective Long Valley geothermal area (NOAA, 1980).

These geothermal areas are commonly underlain by Pliocene and Pleistocene volcanic rocks with cinder cones dispersed over a wide area. These relatively young volcanic rocks indicate the presence of a favorable heat source at depth. Mono basin is described as a shallow, downwarped basin where most of the hot springs, together with the fumaroles and Quaternary cinder cones, are outside the Mono GRA. There appears to be surficial and deep-seated structural and stratigraphic (volcanic strata) continuity with the Long Valley collapsed caldera close by to the south. There is relatively frequent, strong seismic activity throughout the described region.

3. Geothermal Leases

The Mono-Long Valley KGRA which extends from the north end of Mono Valley south to encompass all of Long Valley, is considered one of the most prospective geothermal resource areas in the United States. The western one-third to one-half of the Mono GRA is included in this KGRA. No Federal leases or lease applications are on record within the GRA

or immediately adjacent to it. A Geothermal Lease map is included at the back of the report.

4. Geothermal Deposit Types

The geothermal resources in the Mono and Long Valley areas are believed to be hot-water hydrothermal convection systems of 90° to 150°C and above 150°C, respectively (Muffler, 1979).

5. Geothermal Economics

An indicated measure of the systems size and heat content has been estimated by the U.S. Geological Survey in Circular 790 (Muffler, 1979):

(1) North Shore Mono Lake (Black Rock Point Spring)
(2) Long Valley caldera

(1)	(2)	Characteristics
85°-122°C	200°-250°C	Estimates of reservoir temperature
100° ± 8°C	227° ± 10°	Mean reservoir temperature
3.3 ± 0.9	136 ± 36°	Mean reservoir volume (km^3)
0.77 ± 0.23	78 ± 21	Mean reservoir thermal energy (10^{18} J)
0.193	19.4	Wellhead thermal energy (10^{18} J)
0.046	4.9	Wellhead available work (10^{18} J)
	2100	Electrical energy (MW for 30 yr)

Although the Geological Survey gives an estimated figure for electrical energy potential for Long Valley caldera only, it is probable that the moderate temperature resource at Mono will be capable of supporting electrical power generation as well.

Geothermal resources are utilized in the form of hot water or steam normally captured by means of drilling wells to a depth of a few feet to over 10,000 feet in depth. The fluid temperature, sustained flow rate and water chemistry characteristics of a geothermal reservoir determine the

depth to which it will be economically feasible to drill and develop each site.

Higher temperature resources (above 350°F) are currently being used to generate electrical power in Utah and California, and in a number of foreign countries. As fuel costs rise and technology improves, the lower temperature limit for power will decrease appreciably -- especially for remote sites.

All thermal waters can be beneficially used in some way, including fish farming (68°F), warm water for year around mining in cold climates (86°F), residential space heating (122°F), greenhouses by space heating (176°F), drying of vegetables (212°F), extraction of salts by evaporation and crystallization (266°F), and drying of diatomaceous earth (338°F).

Unlike most mineral commodities remoteness of resource location is not a drawback. Domestic and commercial use of natural thermal springs and shallow wells in the Basin and Range province is a historical fact for over 100 years.

Development and maintenance of a resource for beneficial use may mean no dollars or hundreds of millions of dollars, depending on the resource characteristics, the end use and the intensity or level of use.

D. OTHER GEOLOGICAL RESOURCES

The WSAs in the Mono GRA are not believed to have any other geological resources. There is no potential for coal resources, tar sands or oil shale.

E. STRATEGIC AND CRITICAL MINERALS AND METALS

A list of strategic and critical minerals and metals provided by the BLM was used as a guideline for the discussion of strategic and critical materials in this report.

The Stockpile Report to the Congress, October 1981-March 1982, states that the term "strategic and critical materials" refers to materials that would be needed to supply the industrial, military and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such need. The report does not define a distinction between strategic and critical minerals.

There is potential for tungsten, a critical and strategic metal, in all of the WSAs of the GRA.

IV. LAND CLASSIFICATION FOR G-E-M RESOURCE POTENTIAL

Krauskopf and Bateman (1977) provide detailed geological mapping of the southeast corner of the GRA -- all of WSA CA 010-088S-1/2. Here the quantity and quality of geological data are high, including not only rock types and structure, but also alteration which was mapped at least in the oldest rocks and presumably would have been in the younger ones if alteration had been present. We have a high level of confidence in the data available for this area. In the remainder of the GRA geological mapping is piecemeal, mostly on a small scale, and with little or no attention to alteration or mineralization. The quantity is moderate, and for application to metallic mineral or uranium potential, the quality is low although the quality is adequate for most nonmetallic applications and for geothermal and oil and gas applications. Our level of confidence in the data for this part of the GRA ranges from very low for metals to high for geothermal and oil and gas.

Land classification areas are numbered starting with the number 1 in each category of resources. Metallic mineral land classification areas have the prefix M, e. g., M1-4D. Uranium and thorium areas have the prefix U. Nonmetallic mineral areas have the prefix N. Oil and gas areas have the prefix OG. Geothermal areas have the prefix G. Sodium and potassium areas have the prefix S. The saleable resources are classified under the nonmetallic mineral resource section. Both the Classification Scheme, numbers 1 through 4, and the Level of Confidence Scheme, letters A, B, C, and D, as supplied by the BLM are included as attachments to this report. These schemes were used as strict guidelines in developing the mineral classification areas used in this report.

Land classifications have been made here only for the areas that encompass segments of the WSAs. Where data outside a WSa has been used in establishing a classification area within a WSA, then at least a part of the surrounding area may also be included for clarification. The classified areas are shown on the 1:250,000 mylars or the prints of those that accompany each copy of this report.

In connection with nonmetallic mineral classification, it should be noted that in all instances areas mapped as alluvium are classified as having moderate favorability for sand and gravel. All areas mapped as principally limestone or dolomite have a similar classification since these rocks are usable for cement or lime production. All areas mapped as other rock, if they do not have specific reason for a different classification, are classified as having low favorability, with low confidence, for nonmetallic mineral potential, since any mineral material can at least be used in construction applications.

1. LOCATABLE RESOURCES

a. Metallic Minerals

WSA CA 010-088S-1/2

M4-2A. This classification area covers all of this WSA and all of the GRA except those parts covered by M1, M2 and M3. In this classification area the geologic units exposed at the surface are either Tertiary and Quaternary volcanics or Quaternary alluvium and lakebeds. The underlying rocks are older Paleozoic formations and granitic igneous bodies intruded into them during the period when the major Sierra Nevada batholiths were emplaced during the Jurassic. The distribution of these older rocks is not known, since they are covered by the younger rocks. At many places in the region the older rocks host orebodies related to the granitic intrusives, some of which are substantial ones, such as the large copper and iron deposits of Weed Heights and Pumpkin Hollow near Yerington and the major tungsten deposits of Pine Creek and the vicinity. This potential is the reason for the low favorability classification. There is no information as to the presence of such deposits, hence the very low level of confidence.

WSA CA 010-090

M1-3A. This is the area of apparent molybdenum mineralization in the southwest corner of the WSA. Its outline is defined on the basis of the distribution of unpatented claims. Unconfirmed reports that the molybdenum prospect was drilled are the reason for the moderately favorable classification, while the lack of confirmation of the reports, and the lack of information concerning results, are the reasons for the very low level of confidence in this classification.

M2-3A. This is the area of scattered old diggings at the north end of Granite Mountain in the south-central part of the WSA. Nothing is known about the mineralization here -- including metals present, production, and nature of the occurrence. The presence of the diggings and the fact that one is labelled "mine" on the Cowtrack Mountain 15-minute topographic quadrangle, is the basis for the classification, while the lack of other information is responsible for the low level of confidence.

M3-1B. This area also is in the south-central part of the WSA. In it the pre-Tertiary granite is exposed nearly everywhere, and the total lack of old diggings or other information concerning mineralization indicates that the granitic terrane is barren of mineralization. This is the

reason for the very low favorability and the moderate level of confidence.

M4-2A. This classification area covers the remainder of WSA CA 010-090 and is defined above. The favorability is in the older rocks under the Tertiary and Quaternary cover.

WSA CA 010-092

M4-2A. This classification area covers all of the WSA. As described above, the favorability is in the older rocks under cover.

b. Uranium and Thorium

WSA CA-010-092

U1-2B. This land classification covers the entire WSA and indicates low favorability for uranium in the area with a low confidence level. The WSA is covered by Quaternary lake sediments and dune sands. These lake sediments are partially tuffaceous and could be possible source and host rocks for uranium. Uranium could also be transported in ground water from the Pliocene rhyolites to the east of the WSA. This area has low favorability for epigenetic sandstone-type uranium deposits, though none have been found in or near the area.

There is no favorability for thorium occurrences with a very low confidence level, as there are no thorium source rocks in or near the area.

WSA CA-010-090

U1-2B. This land classification covers the western part of the WSA and indicates low favorability with a low level of confidence for epigenetic sandstone type deposits as discussed under WSA CA-010-092. Thorium is not considered favorable in the area at a very low confidence level, as there are no thorium source rocks in the area.

U2-2A. This land classification area covers the central and eastern portions of the WSA and the GRA. Pliocene olivine basalts have been extruded over this area. These basic volcanics have historically been poor as both a uranium source and host rock, however, the basalts probably overly Cretaceous granitic rocks as are exposed in area U3-3B, and for this reason this area is designated as having low uranium and thorium favorability at a very low confidence level. Durham and Felmlee (1980) indicate a small aerial radiometric uranium anomaly on the eastern

border of the WSA. The anomaly is over Pliocene basalts and Quaternary alluvium.

U3-3B. This land classification area, indicating moderate uranium favorability at a low confidence level, covers the southern portion of the WSA where Pleistocene tuffs, Recent tuffs and Cretaceous granitic rocks crop out. The tuffs and granites are possible uranium source and host rocks. The tuffs are probably related to extrusive events of Mono Crater, just southwest of the WSA. Large uranium deposits have been found associated with tuffs around the edges of such calderas in Nevada, as at the McDermitt caldera. Vein-type and fracture fill uranium deposits are prospective in the area and local primary uranium mineral concentration may occur in the granitic rocks, particularly in pegmatites.

Thorium has low favorability for accumulation in the area at a low confidence level. Deposits would most likely be local mineral concentrations in pegmatites of the Cretaceous intrusion.

U4-2B. This land classification covers the southeastern edge of the WSA and indicates low favorability for uranium concentration at a low level of confidence. The area is covered by Quaternary alluvial deposits. Epigenetic sandstone-type uranium deposits are prospective in the area, with the granites and tuffs to the west being a possible uranium source.

Thorium also has low favorability at a low confidence level for resistate mineral concentration (i.e. monazite sand) in the alluvium. The source of the thorium minerals could be the Cretaceous granitic rocks of Granite Mountain to the west.

WSA CA-010-088S-1/2

U2-2A. This land classification area includes most of the three sections of the WSA. Mesozoic granitic rocks which probably underly the olivine basalts in the area are considered to have low favorability for uranium and thorium deposits at a very low confidence level as discussed under WSA CA 010-090.

U4-2B. This land classification area covers part of two sections of the WSA. It is composed of Quaternary alluvium and has low favorability at a low confidence level for epigenetic sandstone type uranium deposits. A possible source for uranium may be Cretaceous granitic rocks and Miocene rhyolites which underlie parts of the Pliocene basalts north and east of the area. Uranium carried in ground waters from these rocks could be deposited in permeable alluvial sands.

The area has no favorability for thorium deposits, with a very low confidence level.

c. Nonmetallic Minerals

WSA CA 010-088S-1/2

N1-3C. This is the area of Quaternary alluvium covering Adobe Valley and extends into all three seqments of the WSA, at least a little bit. The alluvium, by definition, contains sand and gravel, but none is known to have been produced; hence the moderate favorability classification. The quality of the sand and gravel at any particular point is unknown, which is the reason for the only moderate level of confidence.

N5-2B. This classification area covers all of the GRA except those parts covered by areas N1, N2, N3, and N4, which are classified on the basis of the alluvium in them. This classification area is not known to have any nonmetallic mineral resources, but virtually any mineral material can become a profitable commodity if someone is sharp enough to develop a market for it.

WSA CA 010-090

N2-3C. This classification area is the alluvium-covered valley east of Granite Mountain. The rationale for the classification is the same as for area N1-3C.

N4-3C. This classification area is the alluvium-covered valley east of area N3-3C. The rationale for the classification is the same as for area N1-3C.

WSA CA 010-092

N5-2B. This classification area covers all of the WSA. It is described above.

2. LEASABLE RESOURCES

a. Oil and Gas

WSAs CA 010-088S-1/2, CA 010-090, and CA 010-092

OG1-1D. There has been no serious oil and gas exploration, nor are there any recorded occurrences of oil and gas in this westernmost sector of the Basin and Range province where it meets the Sierra Nevadas. The WSAs are underlain by granitic rocks of the Sierra Nevadas and Pleistocene/Pliocene volcanics, in part blanketed by

Quaternary sediments. There are petroleum source beds present in the GRA. There is no oil and gas lease map, nor an oil and gas occurrence and land classification map in this report.

b. Geothermal

WSAs CA 010-090 and CA 010-092

G1-4D. This smaller segment of the GRA is entirely within the Geologic Survey's Mono-Long Valley KGRA and includes at least one favorable hot spring area.

WSA CA 010-090

G2-3C. There is direct geological continuity, both structural and stratigraphic, with the G1-4D classified area. In addition this area is largely underlain by Pleistocene volcanics, which are indicative of a heat source still present at a relatively shallow depth.

WSAs CA 010-088S-1/2, CA 010-090, and CA 010-092

G3-3B. This portion of the Mono GRA is underlain by Pliocene volcanics, and has structural continuity with both the Mono and Long Valley geothermal areas. Outside the GRA to the east, warm waters have been recorded at Bertrand Ranch Springs in Benton Valley and in BLM No. 2 well in Huntoon Valley (Nevada).

c. Sodium and Potassium

S1-1D. All of the WSAs in the GRA are classified 1D with respect to sodium and potassium. There is nothing in the geological environment to indicate any favorability for these commodities.

3. SALEABLE RESOURCES

Saleable resources have been treated above under Nonmetallic Minerals.

V. RECOMMENDATIONS FOR ADDITIONAL WORK

1. The prospects in classification area M2-3A should be field checked to determine what metals are present and their distribution, and to determine whether there is alteration that might have significance.

2. Classification area M1-3A should be examined to determine what alteration is present and if there has been any drilling. Information that earlier was expected from Occidental Minerals was not forthcoming -- the individual there who was supposed to know something about the property said that Occidental had no claims there (despite the evidence of the BLM records).

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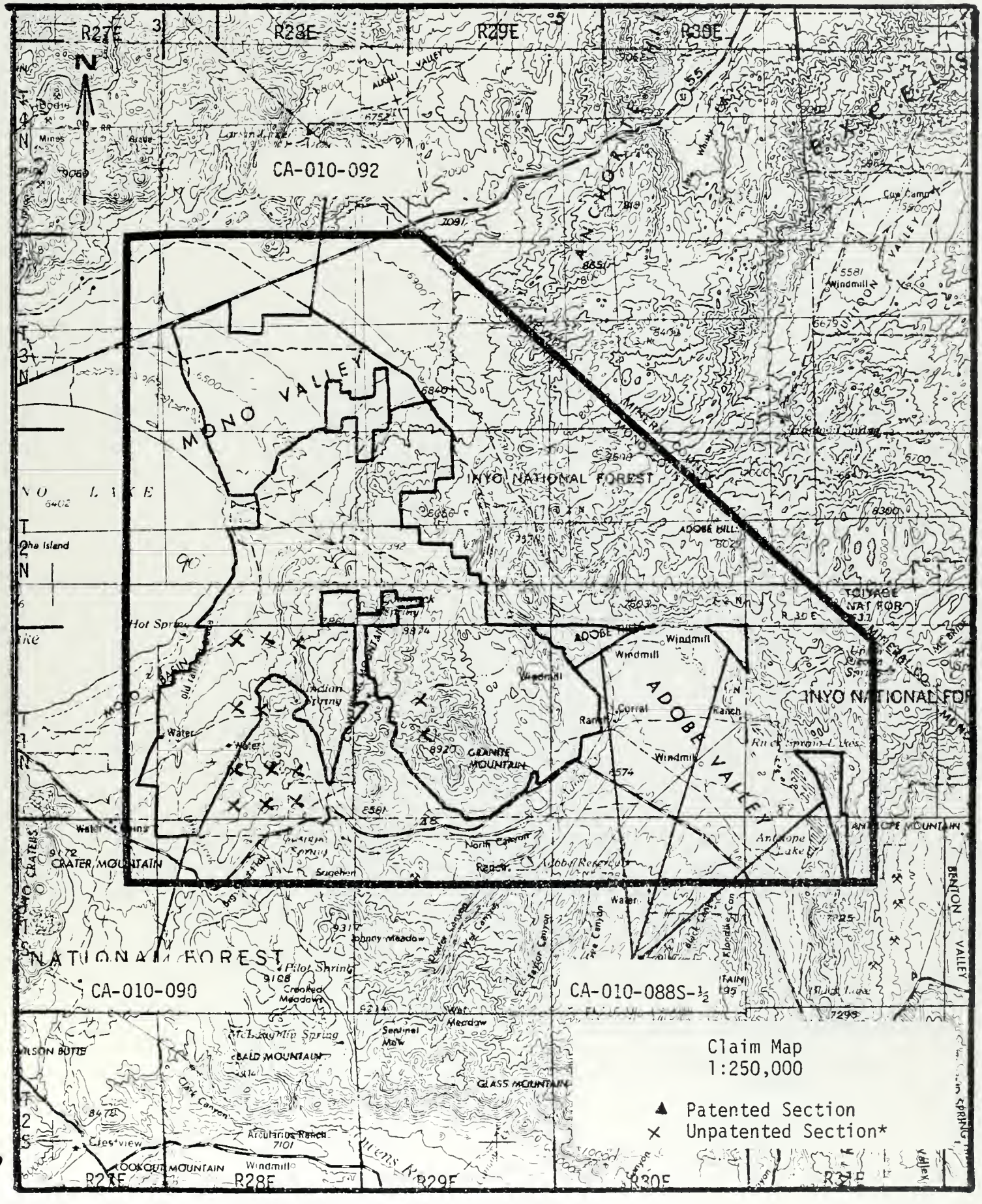
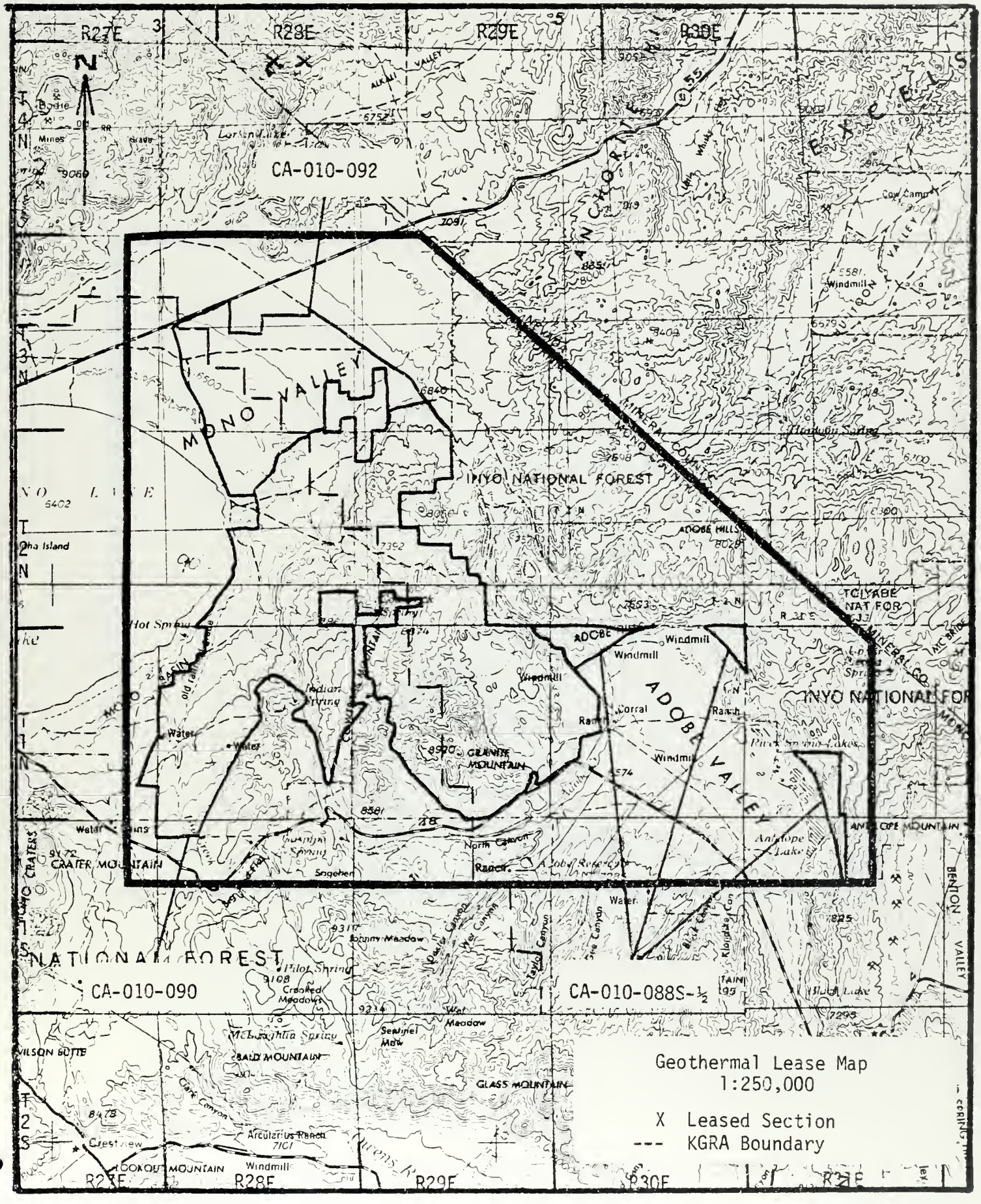


*X denotes one or more claims per section

Mono GRA CA-03



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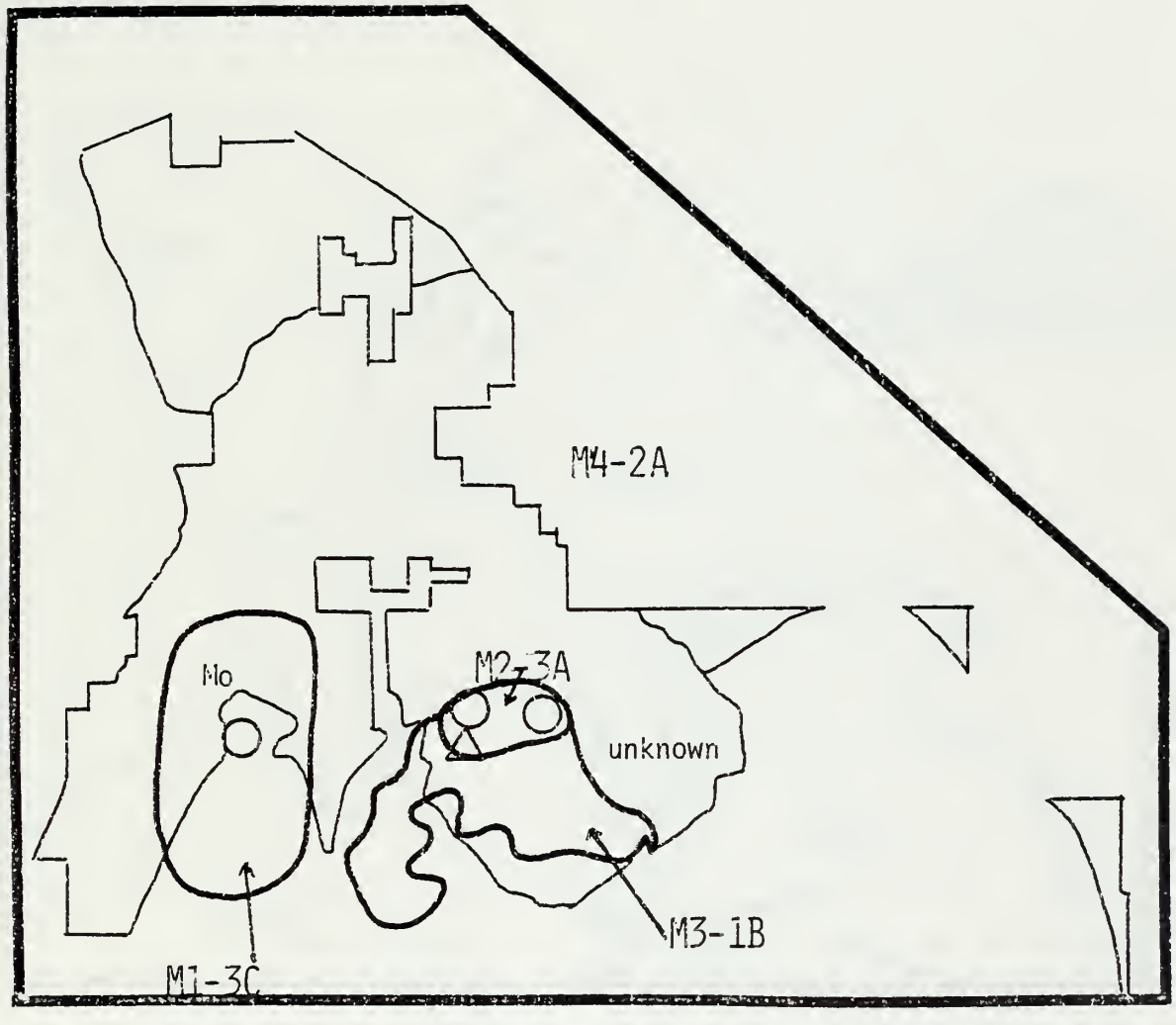


EXPLANATION

— Land Classification Boundary

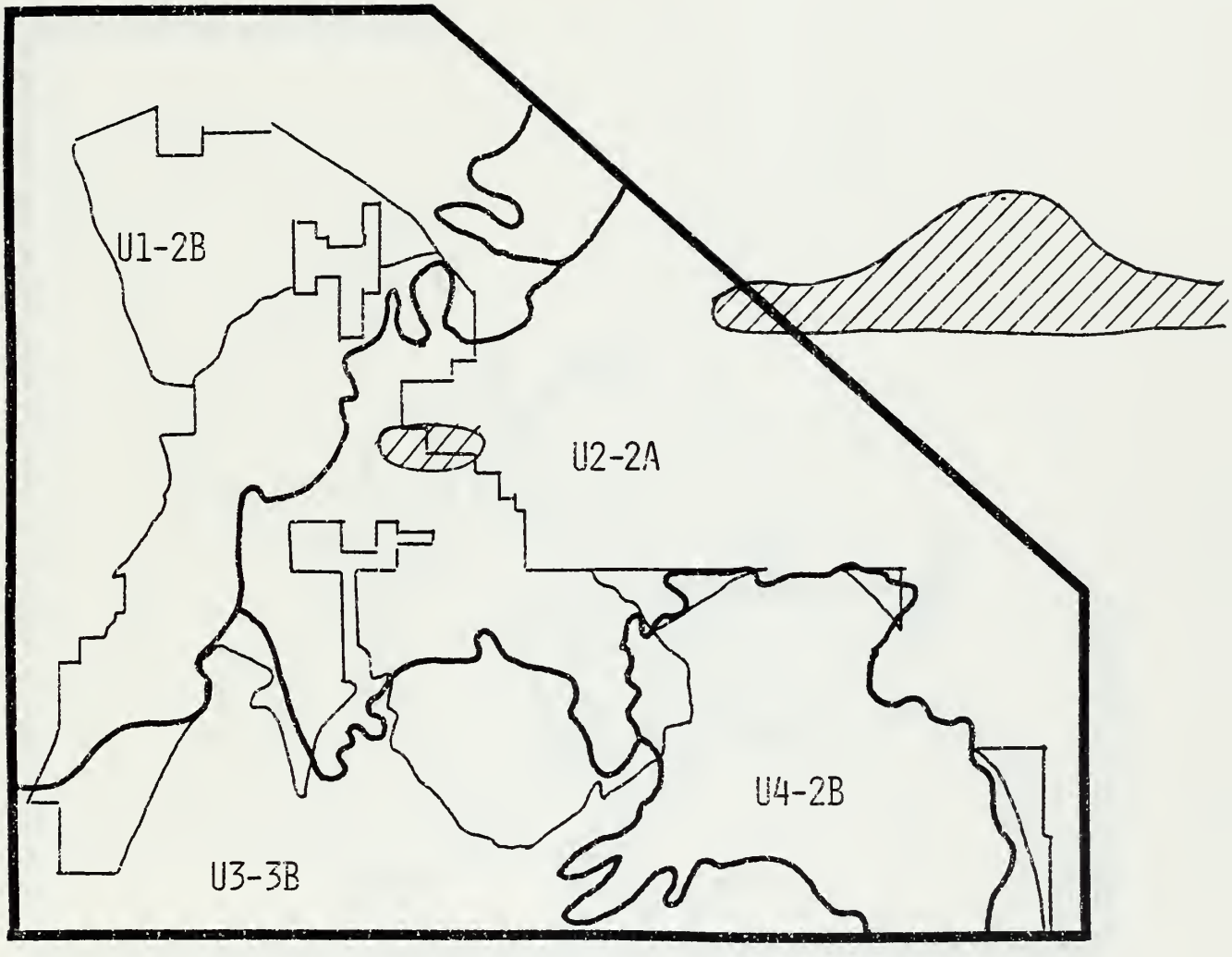
— WSA Boundary

○ Occurrence, commodity

△ Mine, commodity

Land Classification - Mineral Occurrence Map/Metallics

Mono GRA CA-03
Scale 1:250,000



EXPLANATION

Aerial radiometric uranium anomaly

Land Classification Boundary

WSA Boundary

Land Classification - Mineral Occurrence Map/Uranium

Mono GRA CA-03
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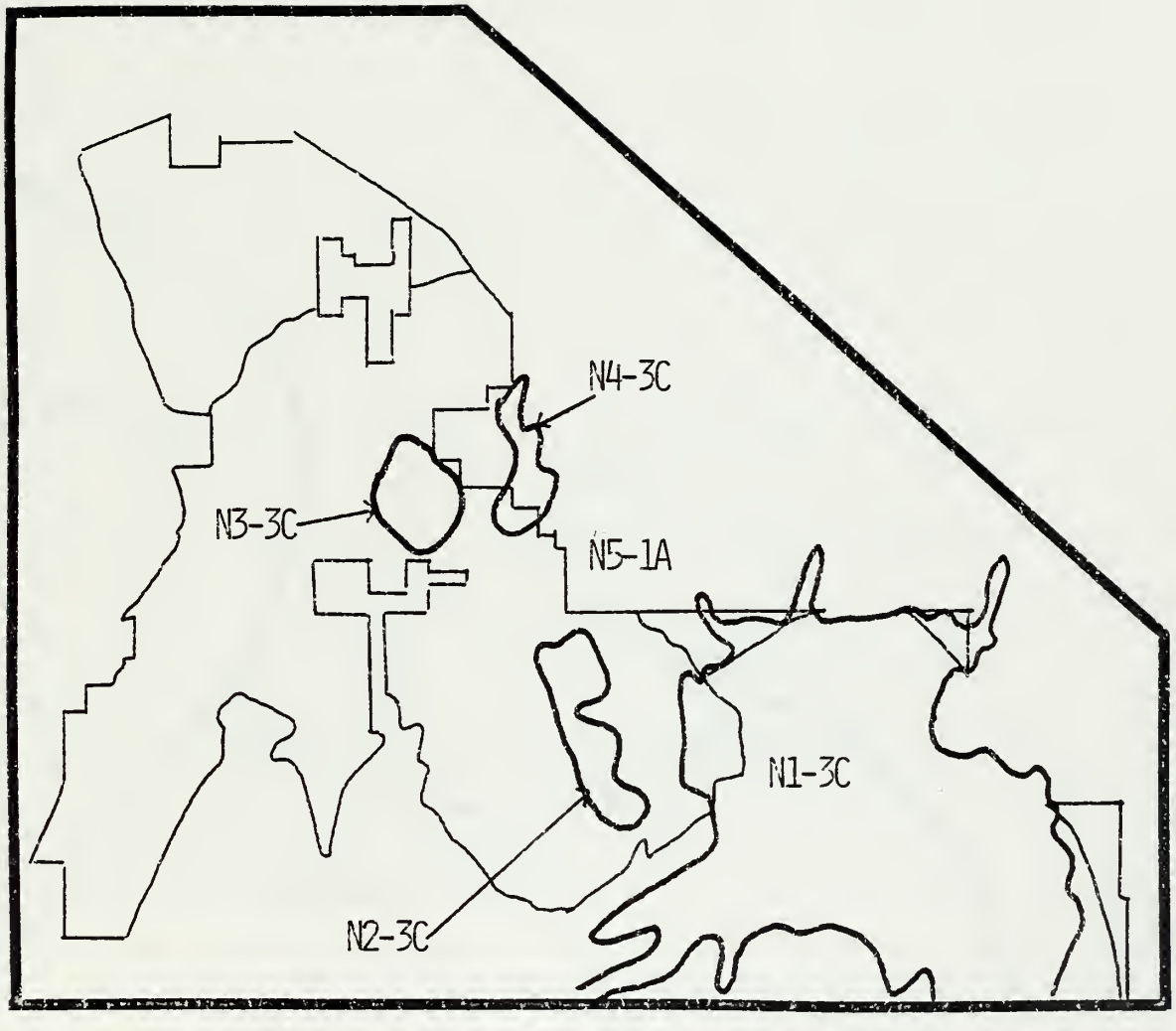


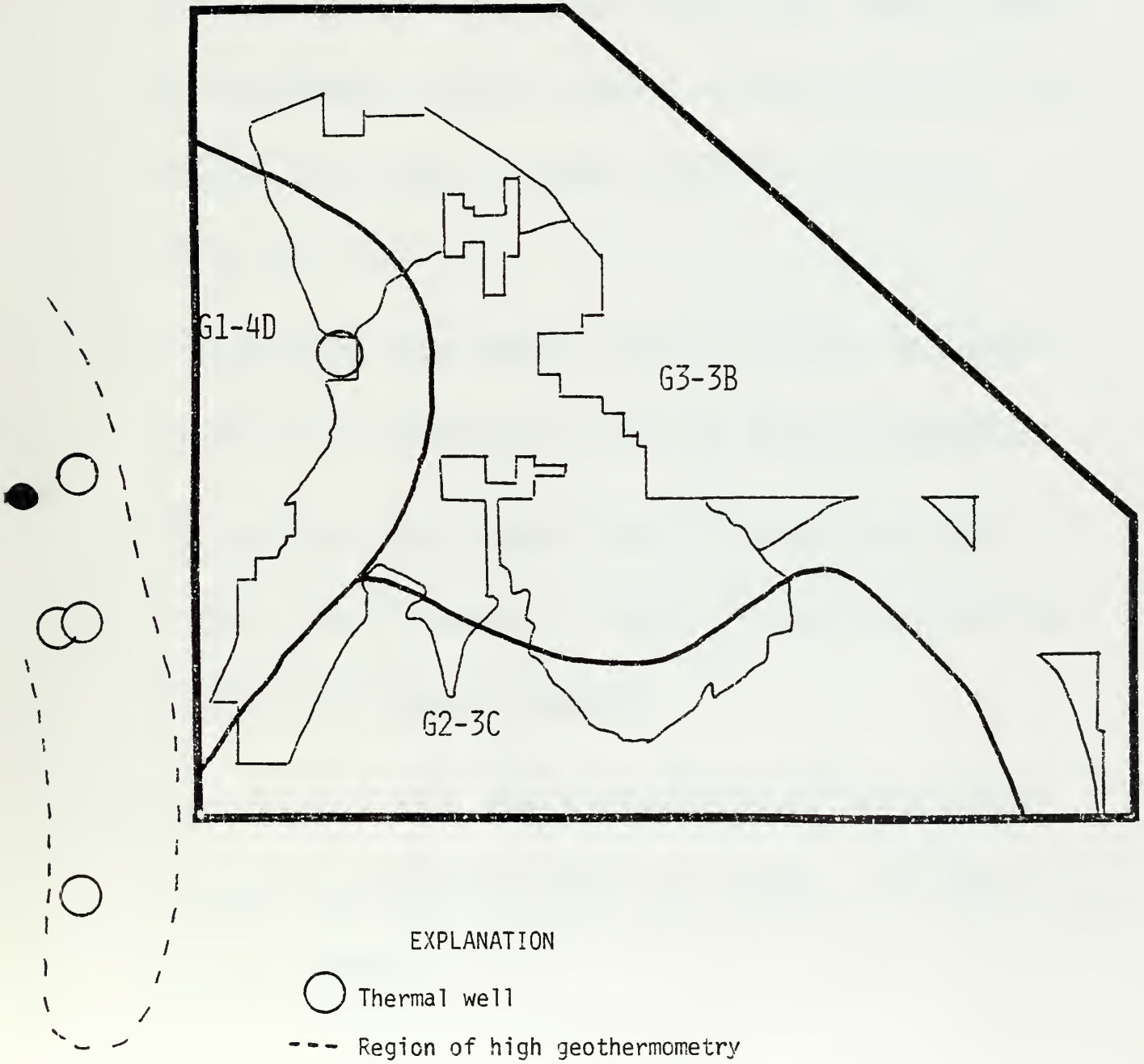
EXPLANATION

Land Classification Boundary

WSA Boundary

Land Classification - Mineral Occurrence Map/Nonmetallics

Mono GRA CA-03
Scale 1:250,000



EXPLANATION

Thermal well

Region of high geothermometry

Land Classification Boundary

WSA Boundary

Land Classification - Mineral Occurrence Map/Geothermal

Mono GRA CA-03
Scale 1:250,000

LEVEL OF CONFIDENCE SCHEME

A. THE AVAILABLE DATA ARE EITHER INSUFFICIENT AND/OR CANNOT BE CONSIDERED AS DIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES WITHIN THE RESPECTIVE AREA.

B. THE AVAILABLE DATA PROVIDE INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

C. THE AVAILABLE DATA PROVIDE DIRECT EVIDENCE, BUT ARE QUANTITATIVELY MINIMAL TO SUPPORT TO REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

D. THE AVAILABLE DATA PROVIDE ABUNDANT DIRECT AND INDIRECT EVIDENCE TO SUPPORT OR REFUTE THE POSSIBLE EXISTENCE OF MINERAL RESOURCES.

CLASSIFICATION SCHEME

1. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES DO NOT INDICATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

2. THE GEOLOGIC ENVIRONMENT AND THE INFERRED GEOLOGIC PROCESSES INDICATE LOW FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

3. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, AND THE REPORTED MINERAL OCCURRENCES INDICATE MODERATE FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

4. THE GEOLOGIC ENVIRONMENT, THE INFERRED GEOLOGIC PROCESSES, THE REPORTED MINERAL OCCURRENCES, AND THE KNOWN MINES OR DEPOSITS INDICATE HIGH FAVORABILITY FOR ACCUMULATION OF MINERAL RESOURCES.

MAJOR STRATIGRAPHIC AND TIME DIVISIONS IN USE BY THE U.S. GEOLOGICAL SURVEY

Erathem or Era	System or Period		Series or Epoch	Estimated ages of time boundaries in millions of years
Cenozoic	Quaternary		Holocene	
			Pleistocene	2-3 [1]
	Tertiary		Pliocene	12 [1]
			Miocene	26 [2]
			Oligocene	37-38
			Eocene	53-54
			Paleocene	65
Mesozoic	Cretaceous [4]		Upper (Late) Lower (Early)	136
	Jurassic		Upper (Late) Middle (Middle) Lower (Early)	190-195
	Triassic		Upper (Late) Middle (Middle) Lower (Early)	225
Paleozoic	Permian [4]		Upper (Late) Lower (Early)	280
	Carboniferous Systems	Pennsylvanian [4]	Upper (Late) Middle (Middle) Lower (Early)	
		Mississippian [4]	Upper (Late) Lower (Early)	345
	Devonian		Upper (Late) Middle (Middle) Lower (Early)	395
	Silurian [4]		Upper (Late) Middle (Middle) Lower (Early)	430-440
	Ordovician [4]		Upper (Late) Middle (Middle) Lower (Early)	500
	Cambrian [4]		Upper (Late) Middle (Middle) Lower (Early)	570
Precambrian [3]			Informal subdivisions such as upper, middle, and lower, or upper and lower, or younger and older may be used locally.	3,600+ [3]

[1] Holmes, Arthur, 1965, Principles of physical geology: 2d ed., New York, Ronald Press, p. 360-361, for the Pleistocene and Pliocene, and Obradovich, J. D., 1965, Age of marine Pleistocene of California: Am. Assoc. Petroleum Geologists, v. 49, no. 7, p. 1087, for the Pleistocene of southern California.

[2] Geological Society of London, 1964, The Phanerozoic time-scale; a symposium: Geol. Soc. London, Quart. Jour., v. 120, supp., p. 260-262, for the Miocene through the Cambrian.

[3] Stern, T. W., written commun., 1968, for the Precambrian.

[4] Includes provincial series accepted for use in U.S. Geological Survey reports.

Terms designating time are in parentheses. Informal time terms early, middle, and late may be used for the eras, and for periods where there is no formal subdivision into Early, Middle, and Late, and for epochs. Informal rock terms lower, middle, and upper may be used where there is no formal subdivision of a system or of a series.

GEOLOGIC NAMES COMMITTEE, 1970